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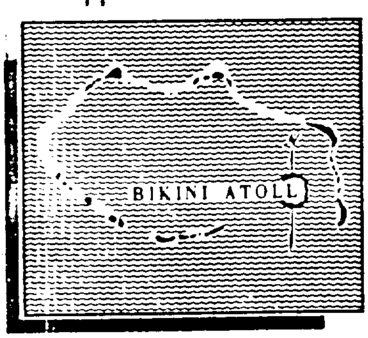
Operation CASTLE

PACIFIC PROVING GROUNDS

March – May 1954

REPORT OF COMMANDER, TASK GROUP 7.1

DELETED VERSION ONLY



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JOINT TASK FORCE SEVEN

[redacted]

ILLUSTRATIONS (Continued)

TABLES

[redacted]

CHAPTER 2

SUMMARY OF EXPERIMENTAL PROGRAMS

2.1 TASK UNIT 1 PROGRAMS (LARGELY LASL)

2.1.1 Introduction

The function of Task Unit 1 (TU-1) was to carry out experiments which would provide information desired by LASL to help in the design of thermonuclear devices. For further information on the purpose of measurements and analysis of results, reference should be made to the reports of the individual projects. Most results presented here are tentative. Their analysis is not complete, and the numerical values given are subject to change in the final reports.

2.1.2 Yield Analysis

The J-10 Group of LASL analyzed the fireball data obtained by Project 13.1, using the "analytic solution" method described in WT-9001 by Francis Porzel. They also provided an early value of the yield based on the difference in time between arrival of the air shock wave and the arrival of a hypothetical sound wave starting at the same time. This method is dependent on knowledge of wind direction and velocity at zero time at the firing site.

The results of these and various other hydrodynamic methods of determining yield are given in Table 2.1.

2.1.3 Program 11, Radiochemistry

(a) Objectives

1. To determine the fission yield of the devices.
2. To ascertain, where possible, what nuclear reactions take place in the devices.
3. To study specific aspects of the reactions by radiochemical tracers placed within the devices.
4. To look for new heavy elements in the bomb debris.

(b) Techniques

1. Samples of the radioactive material from the cloud were obtained by manned aircraft. The samples were flown to Los Alamos for analysis. The fraction of the bomb in the sample was determined by measuring the amount of [redacted] in the sample. Each of these measurements gives a separate value for the bomb fraction in the sample.

Measurement of various fission fragment activities gives the number of fissions represented by the sample. Dividing this by the bomb fraction gives the total number of fissions and therefore the fission yield.

No satisfactory method has been devised to measure the fusion yield by radiochemistry.

[redacted]

WL/HO

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2. Np^{239} is produced by capture of a neutron in U^{238} and subsequent decay, U^{240} is produced by neutron capture in U^{239}, and U^{237} is produced by fast (6 Mev) neutrons on U^{238} by an (n,2n) process. Measurements of the ratio of these isotopes to the total number of fissions give information about the neutron economy and neutron fluxes. Sufficient U^{237} is produced in the devices to permit measurement of its fission cross section on separated samples.

Table 2.1 — YIELDS BY HYDRODYNAMIC METHODS (MEGATONS)

Method	
Time difference*	
Time of arrival	
Pressure-distance	
Time of minimum (Bhangmeter)	
Fireball ϕ^5 scaling	DELETED
Analytic solution	
Weighted average yie Mt	

*Spread of data covering Sandia's close stations to shipboard data.
†Field value of May 1.

Table 2.2 — RADIOCHEMICAL RESULTS

DELETED

3. Various radiochemical tracers were placed inside the devices. Most of these were intended as tests of the tracers, but those in the [redacted] DELETED

4. Portions of the samples were separated and counted in the Forward Area in an effort to find new, possibly short-lived, heavy elements found by multiple neutron capture. Additional analysis for such elements was conducted on the samples received at Los Alamos.

(c) Results

1. The results of measurement of fission yields by various methods are given in Table 2.2.

[redacted]

2. Ratios of Np^{238}, U nd U^{237} to fissions for the various devi are also given in Table 2.2. The U^{237} fission cross section is apparently very similar to Np^{237} except for a lower threshold.

3. No new heavy elements were found in the shot debris. Fall-out after the first shot raised the background at Eniwetok to the point where it largely offset the advantage of obtaining samples early. A new plutonium beta emitter with a 13-hr half life, Pu^{245}, with a 2-hr alpha daughter emitter, Am^{245}, was foun[redacted]

2.1.4 Program 12, Reaction History

(a) Objectives

1. To measure alpha* of the primary bomb [redacted]
2. To measure the time interval between the primary and secondary bombs [redacted]
3. To measure the velocity of propagation of the bur[redacted]
4. To measure the temperature of the thermonuclear reaction by means of the neutron spectrum [redacted]
5. To study the rise of the thermonuclear reaction by observing gamma rays.

(b) Techniques

1. The [redacted] device was fired on land in order to permit detailed study of the reactions. This study was accomplished by collimation of radiation from various parts of the device and propagation of the radiation to a detector station down a manifold of 12 vacuum pipes.
2. The [redacted] device was fired on a barge; therefore collimation upon separate spots was difficult. However, a large shield on the barge suppressed radiation except from limited regions about the primary and secondary reactions. Further collimation at the detector station on shore at a distance of 2300 yd from the barge kept scattered radiation, which might have spread the signal out in time, from reaching the detectors.

(c) Results

1. See Table 2.4 for alpha measurements.
2. See Table 2.6 for time-interval measurements.

[redacted]

4. A good neutron spectrum was obtained [redacted] The position of the peak may indicate a disassembly velocity of [redacted] Analysis for temperature is proceeding. Loss of most of the scattered neutron-spectrum data on other channels may make it impossible to separate wall acceleration from temperature broadening of the spectrum.

[redacted]

2.1.5 Program 13, Diagnostic Photography

(a) Objectives

1. To measure fireball radius vs time.
2. To measure cloud rise and to photograph cloud development.
3. To measure the time to the light minimum for purposes of yield scaling.
4. To photograph the bomb case for approximately the first 10 μsec.
5. To test a system for measuring temperature and opacity at temperatures such as 1 kev.
6. To measure the shock velocity in the bomb case as the region inside is heated.
7. To measure the time interval between primary and secondary reactions.

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*In a supercritical assembly the number of fissions increases in time as $e^{\alpha t}$.

[redacted]

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(b) Techniques

1. Cameras were placed on towers at distances of 10 to 20 miles to photograph the early growth of the fireball and to measure cloud rise.

2. Bhangmeters were placed on the Enyu tower for the Bikini shots and on Parry for the Eniwetok shot. These devices record light intensity as a function of time.

3. Nominal three million frames/sec framing cameras were used to observe the bomb case from recording shelters near the bomb, where possible. [redacted] observed from a distance of 10 miles since the close shelter was destroyed on the first shot.

4. For the temperature-opacity measurement DELETED a system of pipes, collimators, and turning-mirror towers was set up to observe the travel time of radiation through various materials [redacted] In addition, shock arrival through the case and through pads on the case at the same distance from the primary was observed. Records were made on Bowen streak cameras.

5. Bowen streak cameras looking at the case and surrounding air were used to measure the time interval between reactions.

(c) Results

1. Fireball radius vs time pictures were obtained on all Los Alamos shots.

2. The early cloud-rise velocity was approximately 510 ft/sec DELETED.

3. Bhangmeter results are given in Table 2.1.

4. The recording shelter at 7500 ft from zero failed under the blast pressure DELETE Case pictures were obtained [redacted] There was no evidence of case rupture.

5. Photomultiplier records were recovered from the damaged station DELETED. They indicated that the rate of rise of the light signal in two typical channels had been too slow for the desired temperature-opacity measurement. The streak pictures were fogged by gamma radiation.

6. The time interval between primary and secondary reactions, as measured by various methods and observers, is shown in Table 2.6 together with the predicted values.

2.1.6 Program 14, Threshold Detectors

(a) Objective

To determine the total number of neutrons above various threshold energies leaving the devices.

(b) Techniques

1. Samples were placed at various distances from the devices for activation by neutrons arriving at the samples. Activation was compared with that produced by known fluxes of neutrons in the laboratory, and the measured flux was extrapolated back to the source. In some cases differences in spectrum between calibration neutrons and bomb neutrons could introduce appreciable error into the results, as could errors in the extrapolation. Table 2.3 gives detectors used and their thresholds.

2. Information about the number of neutrons leaving the devices may be obtained from measurement of the gamma rays arising from neutron capture in nitrogen. This analysis is obscured at early times by inelastic-scatter gammas from the bomb materials and in late stages by lack of knowledge of neutron diffusion and hydrodynamics.

Survey experiments were made [redacted] with two forms of gamma detectors having thresholds to eliminate low-energy gammas from inelastic scatter and fission, leaving mostly the desired capture gammas. One detector used pulse-height discrimination and the other used Cerenkov radiation to provide thresholds.

(c) Results

1. Table 2.5 gives integrated neutrons at the devices as measured by the various detectors, together with the measurements of total neutrons made by Program 16.

[redacted]

2. Gamma-ray measurements made as a function of time with threshold gamma detectors were made [redacted] The pulse-height discrimination system [redacted] with a threshold of approximately [redacted] recorded a gamma signal [redacted]

DELETED

2.1.7 Program 15, Alpha Measurement

(a) Objective

To determine, by measuring alpha,* whether or not the primary bombs in the various devices operated properly.

(b) Techniques

1. A large fluorescent plastic, capable of rapid time response, was erected near each of the Castle devices and viewed from a distance of 3 to 10 miles by a 2-ft-diameter telescope. When excited by gamma rays it fluoresced. Light from the telescope was collimated at the image point and passed on to photomultiplier tubes. The output signal was amplified and displayed on oscilloscopes.

2. This system had not previously been checked out in an actual bomb test, although similar systems were tried at Upshot-Knothole. It was therefore used as a backup on the first shot, where an orthodox photocell detector was in operation. On the remaining LASL devices it was the primary method of alpha measurement.

3. An attempt was made to measure alpha by observing the electromagnetic signal generated by the nuclear reaction. This signal also contains information on the time interval between primary and secondary reactions.

(c) Results

1. The results of the various alpha measurements are given in Table 2.4. In addition to the estimated probable error indicated, there remains an unexplained scatter in results on some shots. Further study of photomultiplier-tube operation will be made in an effort to reduce this. The table indicates that the [redacted] device may have been as much as 10 per cent low in yield. DELETED

2. Fall-out from the first test made it necessary to move the electromagnetic detector equipment from Bikini to Eniwetok. A fair test of the system for measuring alpha was only

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*In a supercritical assembly the number of fissions increases as $e^{\alpha t}$. Since the device disassembles rapidly when the nuclear energy becomes appreciable, a larger alpha allows more fissions before disassembly and, therefore, more yield. Additional measurements were made [redacted] by Program 12.

DELETED

[redacted]

ball as it swept by the field of view. The Model 6 shows a faint glowing (Teller light?) [redacted] and then a somewhat brighter glow growing in size [redacted]

2.2.4 Program 24, External Neutron Measurements

The object of Program 24 was to measure the energy spectrum of neutrons emanating [redacted] An energy resolution of about 2 per cent should be obtained for the (d,t) peak.

Neutrons from the device coming down the Tenex pipe strike two CH_2 radiators. Recoil protons from (n,p) collisions in the radiators are detected in nuclear emulsions. Measurements of proton ranges in emulsion yield proton energies, from which the neutron energies may be determined.

The signal-to-noise ratio in the exposed plates is good. The single-grain background is small, indicating a negligible exposure to gammas and electrons. Under a magnification of 1000×, there is about 1 recoil proton from fission events per field of view and about 1 recoil proton from the (d,t) reaction per 20 fields of view. When corrections are made for angles of observation, solid angle, radiator thickness, and the (n,p) cross section, the resulting neutron energy spectrum shows a peak at 14 Mev, superimposed on a fission spectrum. [redacted] There is a noticeable tail of the peak toward the low-energy side which would indicate a contribution of scattered 14-Mev neutrons down the pipe. The yield in the 14-Mev peak is about 3 per cent of that expected from the initial calculations where a yield of 1 Mt was taken as the basis for calculation.

2.3 TASK UNIT 13 PROGRAMS (DOD)

2.3.1 Program 1, Blast and Shock Measurements

The broad objective of Program 1 was to measure and study the blast forces transmitted through the various media of the earth. In the main, measurements were obtained in air by means of Wiancko and mechanical self-recording pickups. Those obtained within the water were taken by means of tourmaline, Wiancko, strain gauge, and ball-crusher pickups. A few earth measurements were made, using Wiancko accelerometers. Successful measurements contributing to the fulfillment of the objectives were made by 10 out of 12 projects. Of the two unsuccessful projects, one failure was brought about [redacted] The other project failure was brought about by the scheduled time of firing which imposed unfavorable light conditions for photography.

Many interesting and valuable records were obtained during the shot series. These records were interpreted in the field and will be reexamined subsequently at the home laboratories of the various project agencies. The following tentative conclusions are based on preliminary data and, therefore, are subject to change upon a more careful study of the records.

1. The air shock pressure-time traces obtained at close-in ground ranges were distorted.
2. Although distorted air shock wave forms were noted, no serious peak pressure discrepancies (as compared to the 2W Operation Tumbler-Snapper composite free air pressures) were noted.
3. Dynamic air pressures were obtained that were higher than those predicted by the Rankine-Hugoniot relations applied to air. The pressure discrepancies were probably a result of sand and/or water loading of the shock wave.
4. Within the ranges instrumented (7500 to 20,000 ft), underwater shock pressures were not appreciably larger than the air pressure at the corresponding distance. Approximately equal peak-pressure-inducing signals were transmitted through the earth and air, and these induced peak pressures were approximately equal to those of the air shock wave at corresponding distances.
5. The heights of the water waves induced within the Bikini lagoon can be approximated by the empirical relation

$$H_tR = \frac{2.25W^{1/2}\ (\phi/180)^{1/2}}{\rho}$$

where H_t = shallow water crest height in feet
R = range in feet
W = equivalent charge weight in megatons
ϕ = angular breach width in degrees in a semicircle into the lagoon
ρ = relative density of media beneath fireball

2.3.2 Program 2, Nuclear Radiation Effects

The general objective of this program was the determination of the militarily significant nuclear radiation effects of high-yield surface detonations. Of primary interest was the determination of the nature, intensity, and distribution of radioactive fall-out resulting from surface-land and surface-water detonations of high-yield devices. In addition, the effects of initial gamma radiation and the flux and spectrum quality of neutrons were investigated.

Gamma film- and chemical-dosimetry techniques and gamma scintillation-counter equipments were employed to evaluate initial and residual gamma-radiation exposure and to provide information on arrival time and early field decay characteristics of gamma radiation from fall-out.

Neutron-detection techniques, including the use of a variety of fission and threshold detectors, were employed to document the neutron flux [redacted]

The fall-out instrumentation included a variety of types of collectors, including samplers for total liquid and dry fall-out collection, intermittent collectors, and liquid aerosol collectors. The lagoon and island areas local to the shot zero points were heavily instrumented for all Operation Castle detonations [redacted]

Documentation of fall-out over extensive downwind ocean areas encountered serious experimental and operational difficulties. The problem was attacked initially by the employment of an array of free-floating buoys equipped with sample collectors. [redacted] an area survey was mounted which involved surface and subsurface activity measurements, water sampling, and hydrographic measurements. This survey covered a broad downwind zone to a distance of 200 miles and met with a large measure of success.

Neutron-flux measurements [redacted] and initial gamma data [redacted] established the nature and magnitude of these effects for these types of high-yield surface detonations. Initial gamma radiation and neutrons are of minor significance in relation to other effects of such bursts.

Considerable information was obtained on the distribution and characteristics of fall-out from high-yield land and water surface detonations. Extensive close-in data DELETED were augmented by a postshot survey of numerous downwind islands within the path of the fall-out to a range of 300 miles. The oceanographic and radiological survey [redacted] provided good coverage of the principal zone of downwind fall-out to a range of 200 miles. The results of the latter, plus limited good buoy samples taken 35 to 50 miles downwind [redacted] should allow evaluation of the nature and distribution of fall-out for high-yield surface-water bursts.

These results indicate that surface bursts of megaton yields distribute casualty-producing fall-out over areas upwards of 1000 square miles.

The oceanographic survey [redacted] indicates that the techniques employed, coupled with a rapid synoptic monitor survey of the water surface by fast surface vessels or aircraft or both, provide a feasible method for documentation of fall-out over water areas.

2.3.3 Program 3, Structures

The objective of Program 3 was to study the effects of blast in various areas of military interest. The nature and results of this study are briefed in the following paragraphs.

In Project 3.1 a rigid 6- by 12- by 6-ft cubicle at 9500 f[redacted] was instrumented to record pressure vs time on the cubicle faces. Records were obtained, but the pressure field was on the order of 3.5 psi instead of the order of 15 psi which had been expected on the basis of predicted yield. The data are yet to be analyzed and interpreted.

[redacted]

In Project 3.2 the apparent craters formed by the [redacted] DELETED detonations were measured by fathometer soundings as originally planned. The results are given in Table 2.8.

In Project 3.3 a study was made of tree damage on Eniirikku, Rukoji, and Chieerete Islands [redacted] Graded damage was observed, but data obtained are yet to be analyzed and interpreted. DELETED

Project 3.4 determined the effects [redacted] upon naval mines of various types planted at distances of 2000 to 15,000 ft from the detonation site. Graded damage was obtained from 0 per cent at 15,000 ft to 100 per cent [redacted]

Project 3.5 was activated [redacted] to document the unexpected damage to the camp on Eninman and certain instrumentation shelters near Ground Zero. This was done primarily by photography.

Table 2.8 — CRATER DATA

Crater [redacted]	Diameter, ft	Depth of apparent crater, ft
[redacted]	6500	120
[redacted]	700	24
[redacted]	1500 – 2500	20*

*Below original bottom which was 160 ft below water surface.

2.3.4 Program 4, Biomedical Studies

These studies represented the first observations by Americans on human beings exposed to excessive doses of radiation from fall-out. The groups of exposed individuals are sufficiently large to allow good statistics. Although no preexposure clinical studies or blood counts were available, it was possible to obtain Marshallese and American control groups that matched the exposed population closely with regard to age, sex, and background. Thus the conclusions which may eventually be drawn from group comparisons should be reliable.

The type of radiation received, and the manner in which the radiation dose was delivered, differed in several important respects from that seen in the Hiroshima and Nagasaki casualties, the Argonne or Los Alamos accidents, or in the bulk of animal laboratory radiation exposures. In addition to a wide spectrum of gamma-ray energies in the fission-product field, there was a beta component. Some clinical, and especially laboratory, findings in this study are consistent with a hard penetrating component. The clinical and pathological findings in the skin lesions, as well as the correlation of distribution of the lesions with exposed skin areas, are consistent with a sizable component of extremely soft radiation. The absence of evidence of skin damage deeper than the superficial lesions in the initial biopsies described would argue against a considerable component of radiation of intermediate energy. In addition to external radiation, some internal contamination did occur. The extent and long-term significance of this interval component remains to be evaluated.

Therefore it is probable that the exposed individuals were subjected to essentially three types of radiation: penetrating total-body exposure, beta or soft gamma exposures of the skin, and irradiation of internal organs from radioactive materials in the body. It remains to be evaluated if the various findings observed can each be attributed to one of the different radiation components separately, or if combined effects of these radiations must be invoked to explain some of the findings. There is no good reason to date to suspect possible combined effects from the over-all clinical or dermatological picture observed.

As stated, the meager preliminary information on the skin biopsies taken in the present studies indicates that skin damage was limited to the superficial layers. To date, none of the vascular lesions reported by Lushbaugh et al. as being characteristic of experimental beta

[redacted]

burns have been seen in the biopsy sections. However, the energy of the beta rays in the fall-out may have been very low, thus limiting the injury to the superficial epidermis and sparing the vascularized dermis. Accordingly, the absence of specific vascular lesions in the biopsies would not necessarily eliminate radiation as a causative factor.

The dose rate from fall-out varied continuously, and the total dose was received over a period of many hours or days. This is in contrast to previous experience mentioned, in which the dose can be considered to be either essentially instantaneous or received at a constant dose rate over a period of minutes. From previous animal experimentation it might be expected that the dose received by exposed individuals in the present study, extending over two or three days, would produce less of an effect than would the same total dose given over a few minutes. It is not possible without further experimentation to attempt quantification of the degree to which observed effects in the population studies may have been altered by this particular combination of dose rate and time during which the total dose was delivered.

Hematological findings were somewhat similar to those seen following single doses of penetrating radiation in animals. However, the time course of changes in both the leucocyte and platelet counts in the Rongelap group was markedly different from that seen in animals. Maximum depression of these elements occurred much later in these individuals than is seen in animals, and the trend toward normal was considerably delayed. The marked delay in return to normal leucocyte values in the present study appears to exceed that observed in the Hiroshima and Nagasaki casualties. Further evidence that the return to normal may be later in human beings than in animals can be seen in the response of the few cases of the Argonne and Los Alamos accidents. Although the doses, types, and conditions of irradiations were sufficiently different in the several series of exposed human beings to preclude strict comparisons among them, the added evidence from the present studies would seem to validate the general conclusion that the time pattern of hematological changes following irradiation in man is significantly different from that observed in the large species of animals studied to date.

2.3.5 Program 6, Service Equipment and Techniques

Program 6 included six projects concerned with the developing, testing, and analyzing of various aspects of weapons effects on service equipment and operational techniques.

Project 6.1 was successful in obtaining excellent radarscope photos of the detonation and blast phenomena for utilization in establishing Indirect Bomb Damage Assessment (IBDA) procedures for high-yield weapons.

The high-yield weapons detonated in regions such as Bikini, where sharp land and water contrasts are obtainable, gave excellent results for radar-return studies and air-crew training for the 20 Strategic Air Command (SAC) air crews who participated.

Projects 6.2a and 6.2b were successful in obtaining significant data concerning blast, thermal, and gust effects on B-36 and B-47 aircraft in flight. Minor blast damage was sustained by the B-36 on several shots; however, predictions on temperature rise as a function of incident thermal energy for both the B-36 and B-47 were shown to be conservative. Some concern arose over the response of the B-36 horizontal stabilizer to gust-loading at a critical station. Additional studies will be required, including instrument calibration, before any revisions of current concepts of delivery capabilities can be expected.

Project 6.4 was successful in evaluating the effectiveness of washdown systems for naval vessels. Also much valuable experience was gained in ship-decontamination procedures and techniques. In addition, one vessel (YAG-39) assisted in the collecting of fall-out data for Project 2.5a. Project 6.4 has demonstrated that a typical naval vessel, when adequately equipped with washdown apparatus, can operate safely in regions of heavy fall-out and still maintain operational capability without excessive exposure of the ship's company to residual radiation from fall-out.

Project 6.5, operating in conjunction with Project 6.4, evaluated current decontamination procedures on representative walls, roofing, and paving surfaces which were subjected to the wet contaminant of barge and land shots. The contaminant, particularly from the barge shots,

[redacted]

was found to be much more tenacious than that experienced in similar tests at the Buster-Jangle underground shot, and the accepted decontamination procedures were less effective.

Project 6.6, recordings of effects on ionospheric layers, particularly the F_2 layer, was successful in most instances. Because of radiation levels, the Rongerik station could not be operated continuously for complete ionosphere history, but the station was activated for all shots. The significance of recorded results will require detailed study prior to the writing of a final report.

2.3.6 Program 7, Long-range Detection

The general objectives of Program 7 experiments in this test series were the improvement of present techniques, development of new techniques, and collection of calibration data in furtherance of the AFOAT-1 mission. Participation in the test was really twofold, consisting of some experiments specifically designed for Operation Castle and some operational tests of routine procedures.

The three projects of Program 7 were instrumented to investigate electromagnetic signals, acoustic signals, and particulate and gaseous debris associated with nuclear explosions. Portions of the experiments were conducted at the Pacific Proving Grounds (PPG), but most of the project sites were located at great distances from the detonation points.

In all projects the operational phase of the experiment was successful in that, quantatively, the desired records and debris were obtained. The analytical phase of the experiments was not complete at the time of this report, and qualitative results are not yet available.

2.3.7 Program 9, Cloud Photography

The only technical project in Program 9 was Project 9.1, Cloud Photography. A summary of this project follows.

The purpose of this program was the photogrammetric determination of the various parameters of nuclear clouds as a function of time and the attempt to establish approximate scaling (yield) relations. The most important of these parameters is the rate of rise of the cloud and the area of the cone swept out by the rising material. Of secondary importance are the dimensions and drift of the cloud as functions of time after it has reached maximum altitude.

The operational plan for this project involved the participation of four aircraft equipped with gyro-stabilized mounts holding a K-17 aerial camera and an Eclair 35-mm motion-picture camera. Three of these aircraft were C-54's, with a flight plan which called for altitudes of 10,000, 12,000, and 14,000 ft orbiting around the cloud for the purpose of conducting photography from H-hour until H plus the time required for the cloud to lose its identity. One aircraft, an RB-36, operated at 35,000 ft and conducted photography for a period of 10 min.

The aerial photography and processing of the negatives were the responsibilities of TU-9. The backup terrestrial photography was done by Edgerton, Germeshausen & Grier, Inc. (EG&G), in conjunction with Project 13.2. Analysis of the photography and evaluation of the data are solely the responsibility of EG&G. Program 9 participated in all shots.

As of this date pre-preliminary results [redacted] have been submitted by EG&G. It has been reported, however, that analysis is [redacted]ceeding satisfactorily, and it is believed by EG&G personnel conducting the photogrammetric analysis that preliminary and final data results will exceed in accuracy the preoperational expectations.

[redacted]

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Table 3.1 — KEY PERSONNEL, TASK GROUP 7.1

Unit or Section	Name
Commander	W. E. Ogle
Deputy for UCRL	Duane C. Sewell
	Walter D. Gibbins
Deputy for Administration	Duncan Curry, Jr.
Advisory Group	
T-Division, LASL	J. Carson Mark
UCRL Scientific	Edward Teller
Radiological Safety	Russell H. Maynard, CAPT, USN
Coordination	Earl A. Long
Safety	Roy Reider
Health	Thomas L. Shipman
	Thomas N. White
Classification and Technical Reports	Ralph Carlisle Smith
	Joseph F. Mullaney
J-1, Personnel and Administration	Armand W. Kelly
	Larry W. Burns
	Robert B. Cruise, Lt Col, USA
J-3, Plans and Operations	Philip L. Hooper, Col, USA
	Walter T. Kerwin, Col, USA
	David V. Miller, Col, USAF
J-4, Logistics	Harry S. Allen
	Robert J. Van Gemert
	John W. Lipp, Lt Col, USA
J-6, Test Facilities	Robert H. Campbell
	Robert W. Newman
TU-1, LASL Programs	Rodney L. Aamodt
Program 11, Radiochemistry	Roderick W. Spence
	Harold F. Plank
	Charles I. Browne, Maj, USAF
Programs 12 and 16, Reaction History and Gamma Intensities at Late Times	Bob E. Watt
	Stirling A. Colgate
	George L. Ragan
Program 13, Diagnostic Photography	Gaelen L. Felt
	Herbert E. Grier
Program 14, Threshold Detectors	Leon J. Brown
	Wendell A. Biggers
Program 15, Alpha Measurement	Newell H. Smith
	Leland K. Neher
	John Malik
	Robert D. England
Program 17, Microbarographic Measurements	John M. Harding
Program 18, Thermal Radiation	Herman Hoerlin
	Harold S. Stewart
Program 19, Marine Survey	Lauren R. Donaldson
	Edward E. Held
TU-2, Production	Herrick L. Johnston
	Nathaniel C. Hallett

[redacted]

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Table 3.1—(Continued)

Unit or Section	Name
TU-3, Special Materials Facilities	Stanley H. Ellison Byron G. MacNabb Dewey J. Sandell
TU-4, LASL Assembly	Marshall G. Holloway Jacob J. Wechsler
TU-6, Firing Party	John C. Clark
TU-7, Rad-Safe	John D. Servis, Maj, USA Ragnwald Muller, LCDR, USN William R. Kennedy Pasquale R. Schiavone
TU-8, Technical Photography	Loris M. Gardner John D. Elliott Robert C. Crook
TU-9, Documentary Photography	James L. Gaylord, Lt Col, USAF James P. Warndorf, Lt Col, USAF Buford A. Mangum, Maj, USAF
TU-12, UCRL Programs	Arthur J. Hudgins
Program 21, Radiochemistry	Kenneth Street Peter Stevenson William Crane Floyd F. Momyer
Program 22, History of Reaction	Stirling A. Colgate
Program 23, Scientific Photography	William P. Ball
Program 24, External Neutron Measurements	Stephen R. White
TU-13, DOD Programs	Huntington K. Gilbert, Col, USAF Neil E. Kingsley, CAPT, USN
Program 1, Blast and Shock Measurements	Walton L. Carlson, CDR, USN
1.1	Casper J. Aronson
1.2a, 1.3, and 1.7	John M. Harding
1.2b	Julius J. Meszaros
1.4	William J. Thaler, J. P. Walsh
1.5	J. W. Smith
1.6	R. R. Revelle, John D. Isaacs
1.8	Edward J. Bryant
Program 2, Nuclear Radiation Effects	Edward A. Martell, Lt Col, USA
2.1	Robert H. Dempsey, Maj, USA
2.2	Peter Brown
2.3	Thomas D. Hanscome
2.5a and 2.6a	E. R. Tompkins
2.5b	Edward F. Wilsey
2.6b	R.C. Tompkins
2.7	T. Folsom
Program 3, Structures	Neil E. Kingsley, CAPT, USN
3.1	Laurence M. Swift
3.2	Robert B. Vaile, Jr.
3.3	Wallace L. Fons
3.4	James Murphy, LCDR, USN
3.5	Wayne J. Christensen, LCDR, USN
Program 4, Biomedical Studies	Edward P. Cronkite, CDR, USN

[redacted]

Table 3.1 — (Continued)

Unit or Section	Name
Program 6, Service Equipment and Techniques	Donald I. Prickett, Lt Col, USAF
6.1	Rockly Triantafellu, Lt Col, USAF
6.2a	G. Miller
6.2b	C. L. Luchsinger
6.4	George G. Molumphy, CAPT, USN
6.5	Joseph C. Maloney
6.6	Albert Giroux, Capt, USA
Program 7, Long-range Detection	Paul R. Wignall, Col, USAF
7.1	J. A. Crocker
7.2	G. B. Olmstead
7.4	Walter Singlevich
Program 9, Cloud Photography	Jack G. James, Lt Col, USAF
TU-14, UCRL Assembly	Paul Byerly
TU-15, Timing and Firing	Herbert E. Grier Bernard J. O'Keefe

Table 3.2 — CASTLE FIRING SCHEDULES

Order		Date	Location	Code name
		Actual		
1	DELETED	3/1/54	Bikini, reef, 2500 yd southwest of Namu	Bravo
2		3/27/54	Bikini, barge, [redacted]	Romeo
3		4/7/54	Bikini, Eninman	Koon
4		4/26/54	Bikini, barge, 2300 yd south of Yurochi	Union
5		5/5/54	Bikini, barge, [redacted]	Yankee
6		5/14/54	Eniwetok, barge, Elugelab crater	Nectar
		Canceled	Eniwetok, Eberiru	Echo
		Feb. 4, 1953		
1	DELETED	2/15/54	Elugelab, ground†	
2		2/22/54	Eninman, ground	
3		3/1/54	Bikini, barge or ground	
4		3/11/54	Bikini, barge	
5		3/21/54	Bikini, barge	
6		3/28/54	Eberiru, ground	
		Apr. 7, 1953		
1	DELETED	2/15/54	Bikini, barge, $1\frac{3}{4}$ miles south of Bokororyuru	
2		2/25/54	Bikini, reef, southwest of Namu	
3		3/8/54	Bikini, barge, 2300 yd south of Yurochi	
4		3/17/54	Bikini, barge, [redacted]	
5		3/24/54	Bikini, Eninman	
6		4/3/54	Eniwetok, Eberiru	

Table 3.2—(Continued)

Order	Device	Date	Location	Code name
		Aug. 24, 1953		
1		2/15/54	Bikini, reef, southwest of Namu	
2		2/25/54	Bikini, barge, 2300 yd south of Yurochi	
3	DELETED	3/8/54	Bikini, barge [redacted]	
4		3/17/54	Bikini, Eninman	
5		3/24/54	Eniwetok, Eberiru	
6		4/3/54	Eniwetok, barge, Elugelab crater	
		Oct. 20, 1953		
1		3/1/54	Bikini, reef, southwest of Namu	
2		3/11/54	Bikini, barge, 2300 yd south of Yurochi	
3		3/22/54	Bikini, barge, [redacted]	
4	DELETED	3/29/54	Eniwetok, Eberiru	
5		4/5/54	Bikini, barge, [redacted]	
6		4/15/54	Bikini, barge, [redacted]	
7		4/22/54	Bikini, Eninman	
		Mar. 6, 1954		
2		3/13/54	Bikini, barge, [redacted]	
3		3/22/54	Bikini, Eninman	
4		3/29/54	Bikini, barge, 2300 yd south of Yurochi	
5		4/8/54	Bikini, barge, [redacted]	
6		4/17/54	Bikini, barge, [redacted]	
7	DELETED	4/24/54	Eniwetok, Eberiru	
		Apr. 13, 1954		
4		4/16/54	Bikini, barge, 2300 yd south of Yurochi	
5		4/20/54	Eniwetok, barge, Elugelab crater	
6		4/27/54	Bikini, barge, [redacted]	

* Substituted for [redacted]

† Being surveyed to determine whether radioactively safe for work.

This and all subsequent schedules were based on having acceptable firing weather on the day each shot was scheduled. No such luck was anticipated, however, and in all operational planning weather was a problem of great concern. Completion dates anywhere from two weeks to two months later than scheduled seemed reasonable to expect. The sixth (last) shot was actually fired 29 days after its scheduled date.

By February 1953 the general outline of the LASL, UCRL, and DOD programs had been established. It included the programs covered in this report, with the exception of the following which were added later: Program 4, Biomedical Studies; Program 17, Microbarography; Program 19, Marine Survey; and Program 24, External Neutron Measurements.

During February a UCRL group visited Los Alamos to discuss transport Dewar and construction requirements and scientific programs. At this time it was decided that no additional transport Dewars were required for Castle.

At the same time, through the Task Force, the Chief of the Armed Forces Special Weapons Project (AFSWP) was urged to nominate as soon as possible a commander for TU-13, DOD

[redacted]

Programs, in order that planning for DOD projects could start and construction and other support requirements might be determined. Early in March a meeting was held at Los Alamos with representatives of the Santa Fe Operations Office (SFOO) and AFSWP, including the prospective Commander of TU-13, to discuss the DOD programs and support requirements. At this meeting AFSWP representatives presented a requirement for a barge shot in deep water. As a result of this meeting and the need for further studies by DOD in connection with the proposed deep-water shot, another meeting was scheduled at Los Alamos early in April. Meanwhile, studies of the lagoon-contamination problem and water-wave problem were started.

After the April meeting CTG 7.1 issued a general statement of concept for Operation Castle, including a shot schedule which is included in Table 3.2 under the date of Apr. 7, 1953. This schedule provided for three barge shots and two ground shots at Bikini and one ground shot at Eniwetok. [redacted] of greatest interest to Los Alamos at this time, was scheduled as a ground shot on the reef southwest of Namu at Bikini in order to permit maximum instrumentation. [redacted] (the smaller two of the Los Alamos shots) was scheduled for a location south of Bokororyuru on a deep-water barge secured to that island and the adjoining one by mooring cables. [redacted] the last shot at Bikini with acceptance of some risk of damage to instrumentation on the Eninman complex in order to retain the use of the airstrip on that complex until the last shot was fired. The problem of possible damage to [redacted] installations from Bikini lagoon barge shots continued to cause concern and was studied from time to time thereafter as additional information became available. [redacted]

Late in June a meeting of Project Officers was held in Los Alamos to discuss project plans, problems, and support requirements. Immediately after this meeting the evacuation concept was discussed with CJTF SEVEN. It was decided that at Bikini, for the first shot, and quite possibly for subsequent shots, it would be necessary to evacuate everybody aboard ships, except for a very small Firing Party which would remain in the reinforced-concrete control station on Enyu. At Eniwetok only the capability of emergency evacuation in case of fall-out was required. The possibility that any Bikini shot might make living ashore at Bikini radiologically unsafe was emphasized. The need for adequate shipboard facilities to finish the Bikini operation from afloat was presented at this time and was reaffirmed later when more definite housing, office, laboratory, shop, and work-space requirements became available.
[redacted] the Los Alamos shot of least interest at that time, and the predicted yield [redacted] had become too large to be acceptable to the DOD for a deep-water shot. Therefore this barge shot was moved into the lagoon. The [redacted] barge was moved from the Bikini lagoon to the Mike crater in order to reduce the work load at Bikini and to fire both cryogenics devices at Eniwetok close to the plants which supported them. The schedule at this time is as shown in Table 3.2, Aug. 24, 1953.

By the middle of September, as a result of several readiness meetings, including one held by the Director of the LASL and attended by representatives of interested agencies, it was decided that readiness for the first shot by Feb. 15, 1954 was most improbable, depending as it did on very tight schedules for a number of the elements involved and that Mar. 1, 1954 was a reasonably realistic date for scheduling the first shot. [redacted] on October 20 a seven shot schedule was promulgated (see Table 3.2 [redacted] it only one shot was scheduled at Eniwetok [redacted] Eberiru as the fourth shot. [redacted] moved back to Bikini because of concern about fall-out on and damage to Eniwetok installations. The four barge shots at Bikini were scheduled for one location, 2300 yd south of Yurochi. This schedule held until [redacted] it was radically changed because of fall-out and unexpectedly high yield.

The large yield and the heavy contamination that ensued brought about radical changes in the operational concept and in the shot schedule. The Firing Party was evacuated aboard ship shortly after the shot. Thereafter all personnel at Bikini lived aboard ship, traveled to and from their stations by helicopter or boat, and firing was accomplished by means of a radio link

[redacted]

Since several of the shots involved a certain number of weather delays, the following chronological listing should be sufficient to point out the highlight dates in the history of each device:

[redacted]

Jan. 25	Unit arrived at Eniwetok
Feb. 17	Final assembly completed
Feb. 18	Shipped to Bikini and transshipped to cab on Feb. 20
Feb. 22	Installation in cab completed
Feb. 27	[redacted]
Feb. 28	
Mar. 1	[redacted] detonated

[redacted]

Jan. 25	Unit arrived at Eniwetok
Mar. 4	Final assembly completed
Mar. 5	Unit installed on barge
Mar. 7	Barge departed for Bikini in LSD [redacted]
Mar. 9	Anchoring completed [redacted] and cables checked out
Mar. 11	Exchanged [redacted] cylinders (used small one)
Mar. 12	[redacted]
Mar. 27	[redacted] detonated

[redacted]

Jan. 25	Unit arrived at Eniwetok
Mar. 2	Assembly completed
Apr. 8	Reassembled after postponement and loaded on barge
Apr. 9	Barge departed for Bikini in LSD
Apr. 10	Anchoring completed and cables checked out
Apr. 15	[redacted]
Apr. 26	[redacted] detonated

[redacted]

Mar. 5	Unit arrived at Eniwetok by air
Apr. 10	New [redacted] cylinder [redacted] received and installed
Apr. 14	Final assembly completed after postponements and loaded on barge
Apr. 16	Barge towed to Mike crater at north end of Eniwetok lagoon, anchored, and cables checked out
Apr. 17	Support jacket removed and dummy lugs attached to the case
Apr. 27	[redacted] and nuclear arming completed
May 14	[redacted] detonated

[redacted]

Apr. 16	Unit arrived at Eniwetok by air
Apr. 26	Final assembly completed
Apr. 27	Loaded on barge
Apr. 30	Barge departed for Bikini in LSD
May 2	Anchoring completed [redacted] and cables checked out
May 4	[redacted]
May 5	[redacted] detonated

In general, the detonation of these devices on barges seems to be a satisfactory method and quite practical. Methods for logistic support of the barges were revised during the operation

[redacted]

4.6.7 Supply Element

Supply stations were originally set up on both atolls, Parry station on Eniwetok and Eninman on Bikini Atoll. In addition to its normal functions, Parry supply was responsible for shipping, receiving, and recording all supplies and keeping supplies moving to Forward Areas as required. Eninman station was a base supply, and its function was to maintain sufficient stocks on hand in case additional substations were required to cope with the operational situation. [redacted] the Eninman supply station was contaminated and was therefore eliminated as a supply point. A sea-going barge was procured and set up as a Rad-Safe Control and Supply Station. The construction aboard the barge consisted of two squad tents and portable salt-water showers. One tent was jointly utilized by control and supply elements; the other was a dressing and change station. Two transportainers were procured for storage purposes, and a wooden hot locker was constructed for radiac instruments. The barge was tied up alongside the USNS Ainsworth during recovery and salvage operations.

A table of equipment for this operation was set up and contained a total list of supplies and equipment for this unit. The majority of items listed therein were shipped from Los Alamos and processed through J-4. These articles arrived on dates due and in good condition. Military items of issue were placed on LX orders, to be furnished by the Supply Officer of TG 7.2.

Facilities for laundering contaminated clothing at Parry were adequate.

4.6.8 Radiological Situation Data Summary

(a[redacted] A partial Rad-Safe survey was conducted [redacted] with incomplete results (Table 4.1). Results of this initial survey were conclusive enough to cancel all activities

Table 4.1—[redacted] RADIATION SUMMARY IN ROENTGENS PER HOUR*

Island	Extrapolated H+4 hr	[redacted]	
		+2 days	+7 days
Enyu	40–60	1.0–3.0	0.38–0.40
Bikini	70–125	6.0–9.0	0.8–2.1
Aomoen	25–180	1.2–9.0	0.75
Romurikku	400	20	0.90
Yurochi	600	30	1.0
Namu (Sta. 1200)	125	6.0	0.45–0.6
Crater		0.1	0.02
Bokonejien	1500	75†	
Bokobyaadaa	280	15	2.0
Spit south of Bokobyaadaa (Sta. 1341)	65	3.0	
Airukiiji through Bokororyuru	6.0–10	0.1–0.22	0.025–0.035
Bairoko (30 miles southeast of Enyu)	0.25		

*All readings with radiac instrument AN/PDR-39 except as indicated.
†AN/PDR-18.

for [redacted] The first complete survey was conducted on [redacted] +2 day. As a result of wind conditions [redacted] areas had become spotty in nature; therefore the extrapolated values representing the H+4 hr readings can only be considered approximate. These extrapolated values are based on a $t^{-1.2}$ decay, whereas laboratory analyses indicate a $t^{-1.8}$ decay during this period, thus indicating values in excess of those noted in the table.

[redacted]

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Bikini lagoon contamination of consequence was confined to lagoon areas containing suspended sediment. For the first few days this area was confined to the western quarter of the lagoon. This radioactive sediment washed over the western reef, out through the southwest passage, or settled to the bottom of the lagoon in a period of three days.

No alpha activity was detected in swipes about the living areas of the Task Group.

(b) [redacted] A partial Rad-Safe survey was conducted [redacted] with incomplete atoll results (Table 4.2). Results of this survey indicated no extensive recontamination of the atoll

Table 4.2 — [redacted] RADIATION SUMMARY IN ROENTGENS PER HOUR

Island	Extrapolated H+4 hr	[redacted] +1 day	+2 days	[redacted] back-ground [redacted]
Enyu	0.03	0.03	0.06	0.03
Bikini*	0.20	0.12	0.14	0.12
Aomoen*	0.80	0.80	0.60	0.22
Romurikku*	1.6	1.7	0.75	1.1
Uorikku*	0.8–1.4	1.4	0.85	1.2
Yurochi*	0.8–1.0	1.3	1.0	1.3
Namu*	2000		100	0.6
Bokobyaadaa*	1000	50.0†	55	1.2
Ourukaen	0.04	0.10‡	0.16‡	0.04
Arriikan	0.02	0.40‡	0.32‡	0.02
Eniirikku	0.005	0.005	0.05	0.01
Airukiiji	0.02	0.01	0.08	0.01
Eninman	0.012	0.012	0.06	
Crater		1100§		
Ships			0.02–0.04	

*Contamination [redacted]
†200-ft altitude.
‡Radiation shine from water in southwest passage.
§At 300 ft.

except within the Bokobyaadaa-Namu chain. An unforeseen fall-out of radioactive material less than 5 μ in size did occur [redacted] This fall-out covered the atoll and raised radiation levels by approximately 100 mr/hr. Because of the late period of fall-out, this radiation level would have corresponded to 3.5 r/hr fall-out at H+2 hr.

Because of small particle size this fall-out was much more difficult to decontaminate than the macroscopic particles [redacted]

Secondary fall-out leveled off between 0700–0800M, [redacted] Residual topside levels on ships were Ainsworth, 8 mr/hr; Estes, 12 mr/hr; and Bairoko, 30 mr/hr. Maximum levels were 20 to 45 mr/hr.

Lagoon contamination covered the western quarter of the lagoon [redacted] Lagoon flushing through the southwest passage materially increased background-radiation levels in the vicinity of Ourukaen, Bokoaetokutoku, and Bokororyuru.

(c) [redacted] A partial Rad-Safe survey was conducted [redacted] with incomplete atoll results (Table 4.3). Results of this survey did indicate that Bokobyaadaa, Namu, Eniirikku, Bikini, and the Yurochi-Aomoen chain were materially contaminated. Reentry and recovery were accomplished to a large degree on shot day. No secondary fall-out was detected as results of this shot.

Lagoon contamination was restricted to a V-shaped pattern with apex at Eninman and tips covering the Bokobyaadaa-Aomoen area. A reading of 100 mr/hr was obtained over the Enin-

[redacted]

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man anchorage at H + 4 hr. Enyu anchorage was clear of contamination whereas Bikini anchorage showed traces of contamination at H + 4 hr.

The [redacted] crater was materially different [redacted] in that radiation levels within the crater were dependent on "shine" from the lip of the crater and surrounding "sand dunes."

(d) [redacted] A damage and radiation survey was conducted [redacted] (Table 4.4). This survey covered the eastern and northern islands of the atoll and was conclusive enough to limit reentry to Enyu, Bikini, and Airukiiji on the first day. The survey [redacted] indicated that recontamination was limited to the Yurochi-Aomoen and the Bikini-Enyu sequence of islands. No material secondary fall-out was encountered at Bikini as a result of this detonation.

Table 4.3—[redacted] RADIATION SUMMARY IN ROENTGENS PER HOUR

Island	Extrapolated H + 4 hr	[redacted] + 1 day	+ 7 days	[redacted]
Enyu	0.03	0.03	0.03	[redacted]
Bikini*	5.0	0.67	0.07	0.10
Aomoen*	20.0	2.5	1.6	0.35
Romurikku*	10.0	1.6	0.80	0.50
Uorikku*	5.0	1.0	0.60	0.47
Yurochi*	5.2	1.0	0.60	0.45
Namu*	250	30.0	16.0	1.5
Bokobyaadaa*	600	•	16.0	9.0
Ourukaen*	0.60	0.08	0.02	0.012
Arriikan*	0.50	0.07	0.01	0.008
Eniirikku*	210.0	2.4†	1.8	0.008
Eninman			0.02	0.010
Airukiiji	0.02	0.02	0.02	0.018
Crater	5000	50‡	60	

[redacted]
†Reading at 100 ft.
‡Reading at 200 ft.

Lagoon water was materially contaminated with radioactive sediment. Readings of 4.2 r/hr were obtained at an altitude of 500 ft over Ground Zero. This contamination moved to the west and southwest so that small-boat operations could be conducted in the area. Lagoon flushing through the southwest passage materially increased radiation levels in the vicinity of Ourukaen, Bokoaetokutoku, and Bokororyuru.

(e) [redacted] A damage and radiation survey was conducted at H + 4 hr [redacted] (Table 4.5). This survey covered the islands of the atoll and was conclusive enough to limit reentry to Enyu and Airukiiji on the first day. This survey indicated that recontamination was extensive throughout the atoll and lagoon both to the east and west. No significant secondary fall-out was encountered at Bikini as a result of this detonation.

Lagoon water was heavily contaminated with radioactive sediment. Readings of 1 r/hr were obtained at 100-ft altitude in the vicinity of zero point [redacted] Floating objects revealed readings of 1 to 3 r/hr on shot days. Small boats and barges in Bikini-Enyu anchorage were contaminated to a moderate degree (1 – 6 r/hr). Lagoon flushing through the southwest passage materially increased radiation levels in the Eniirikku-Bokororyuru area.

(f) [redacted] A damage and radiation survey was conducted at approximately H + 4 hr [redacted] (Table 4.6). This survey covered the islands of the atoll and was conclusive enough

[redacted]

Table 4.4—[redacted] RADIATION SUMMARY IN ROENTGENS PER HOUR

Island	Extrapolated H+4 hr	[redacted] +1 day	+4 days	[redacted] Background [redacted]
Enyu*	0.75	0.10	0.03	0.01
Bikini*	70	8.5	0.80	0.03
Aomoen*	140	15.0	2.0	0.40
Romurikku*	140	15.0	2.4	0.40
Uorikku*	85	10.0	1.0	0.36
Namu			1.0	2.5
Yurochi*	85	10.0	1.0	0.40
Bokobyaadaa		1.2	2.2	4.0
Ourukaen		0.01	0.50‡	0.01
Arriikan		0.01	0.60‡	0.01
Eniirikku		0.06	0.10‡	0.90
Eninman Crater		6.5	4.0	100
Airukiiji		0.01	0.01	0.01
Crater* [redacted]†			0.01	0.00

[redacted]

†Reading at 500 ft.

‡Shine from contaminated water.

Table 4.5—[redacted]RADIATION SUMMARY IN ROENTGENS PER HOUR

Island	Extrapolated H+4 hr	[redacted] +1 day	+5 days*	Background
Enyu†	18	2.0	0.44	0.02
Bikini†	225	25	2.0	0.32
Aomoen†	50	6	0.80	1.0
Romurikku†	65	7.5	1.2	1.0
Uorikku†	95	12	2.0	0.25
Yurochi†	95	12	4.0	1.0
Namu†	10		1.0	0.80
Bokobyaadaa			0.95	3.0
Ourukaen†	3.5(?)	0.50‡	0.12‡	0.01
Arriikan†	1.3	0.60‡	0.10‡	0.08
Eniirikku†	0.18	0.01	0.01–1.0	0.03
Airukiiji†	0.505	0.01	0.01	0.01
Crater		1.0§		
Lagoon			80 (west)	

*Final aerial survey. [redacted]

‡Radiation shine from water in southwest passage.

§Reading at 100 ft.

[redacted]

to limit reentry to the southern and eastern islands of the atoll. This survey indicated that radioactive contamination extended north of a line from Bogallua to Piiraai. Secondary fall-out amounting to 2 mr/hr was experienced at Parry [redacted]

Lagoon water was moderately contaminated in the vicinity of the Bogallua-Teiteiripucchi chain and cleared within two days.

Table 4.6 [redacted] RADIATION SUMMARY IN ROENTGENS PER HOUR

Island	Extrapolated H+4 hr	[redacted] +1 day*	+2 days
Eniwetok	0	0	0
Parry	0	0	0
Japtan	0	0	0
Chinimi	0	0	0
Aniyaanii	0	0	0
Chinieero	0	0	0
Runit	0	0	0
Piiraai	0.05	0.006	0.006
Aaraanbiru	0.08	0.01	0.01
Rojoa	0.10	0.01	0.01
Biijiri	0.12	0.014	0.01
Aomon	0.17	0.02	0.02
Eberiru	0.17	0.02	0.02
Rujoru	0.10	0.012	0.02
Aitsu	0.14	0.016	0.02
Yeiri	0.17	0.02	0.02
Bokonaarappu	0.17	0.02	0.02
Kirinian	0.35	0.04	0.04
Muzin	0.42	0.05	0.06
Engebi	0.70	0.08	0.08
Bogon	0.98	0.12	0.14
Bogairikk	?	0.22	0.60
Teiteiripucchi	60.0	6.8	7.0
Cochiti	70.0	8.0	12
San Ildefonso	75.0	8.4	1.0
Ruchi	8.0	0.80	0.36
Bogombogo	3.9	0.44	0.36
Bogallua	2.2	0.26	0.28
Rigili	0	0	
Giriinien	0	0	
Ribaioni	0	0	
Pokon	0	0	
Mui	0	0	
Igurin	0	0	

*Period preceded by heavy rainfall.

4.6.9 Laboratory Data Summary

The bulk of the samples analyzed by the radiation-analysis section of TU-7 were water samples. The specific activities in microcuries per milliliter of approximately 675 lagoon- and drinking-water samples were determined during the course of the operation. Lagoon sampling was carried on to ensure that ships' anchorages were not excessively contaminated. As the operation progressed it became evident that excessively contaminated water could be observed

[redacted]

as a result of the sediment deposited in the water and could be evaluated adequately using only an AN/PDR-39 survey type meter. The maximum contamination encountered in the lagoon anchorages was 8.4×10^{-3} microcurie per milliliter. The average activity varied from 1×10^{-4} to 3×10^{-4} microcurie per milliliter. No ship's drinking water was found to contain any detectable radioactive material.

Air samples collected in fall-out areas by vacuum type air filters and cascade-impactor slides constituted another type of sample analyzed in the field laboratory. Upon those occasions when fall-out was detected on board the USS Bairoko, portable air samplers were periodically turned on as a means to determine whether fall-out was still occurring. The entire filter paper was counted and the activity was noted in counts/min per cu ft of air. Air samplers were also used by the initial survey party. A cascade impactor, installed in the radiac repair shop on board the Bairoko, was utilized to evaluate the inhalation hazard associated with the radioactive particulate matter by determining the percentage of the total activity associated with particles less than 5 μ in diameter. The air samples collected on March 1, when the USS Bairoko received a substantial fall-out [redacted] indicated activities ranging from 455 to 2740 counts/min per cu ft of air. The only cascade-impactor data were also obtained during the fall-out that occurred on the Bairoko. An average of 65 per cent of the activity was found to be associated with particles less than 5 μ in diameter.

Decay-rate measurements and energy determinations were made on various types of samples throughout the operation in an effort to obtain detailed information on the fundamental properties of the radioactive particulate matter. Gamma energies were difficult to obtain accurately due to the low counting efficiency of G-M tubes for gamma radiation and the apparent low energies involved. The latter also made beta-energy determinations more difficult. Gamma energies measured on very active samples varied from 600 to 25 kev. The low gamma energies measured were somewhat surprising. Beta energies varied from 0.2 to 2.2 Mev.

Log-log plots of counts per minute vs time after detonation were utilized to obtain decay-rate data. Samples studied included fall-out samples on the Bairoko, water samples from the lagoon and drinking-water samples from Rongelap, crater samples, and air samples. The following results represent a cross section of the different types of samples studied and the calculated slope of the line obtained by plotting the log of the activity vs the log of the time after detonation.

1. Fall-out sample on the flight deck of the Bairoko [redacted] 1.62.
2. Lagoon sample collected 1220 Apr. 7, [redacted] 1.03 at +8 days and 1.31 at +25 days.
3. Air sample collected Apr. 26, [redacted] 1.19.

The six drinking-water samples from Rongelap indicated an average slope of −1.48 from [redacted] +4.2 days to [redacted] +10 days and a slope of −1.80 until last counted.

Miscellaneous tasks assigned to the radiation-analysis section included the analysis of urine samples for tritium content; examination of food, soil, and water samples obtained on a resurvey mission to Rongelap and Uterik; a study of the decay characteristics of contaminating material on vans being shipped to the United States; and analysis of water samples obtained during a water survey [redacted]

4.6.10 Conclusions and Recommendations

(a) Conclusions. The present maximum permissible exposure of 3.9 r per 13-week test period is not a realistic MPE in consideration of heavy work loads in extensively contaminated areas. The use of waivers to cover exposures in excess of this MPE becomes a needless routine without much significance when operations are conducted in large contamination areas without much interval between detonations. A large number of individuals did exceed 3.9 r, but very few exceeded 6.0 r.

The utilization of project personnel as monitors proved itself with few exceptions.

Procurement and clearance of personnel must be accomplished at least four months in advance of operations in order that selection and training can be completed and in order that the unit can be completely assembled prior to movement overseas.